

BLACK & VEATCH

South Florida Water Management District  
**EAA Reservoir A-1 Basis of Design Report**

January 2006

**APPENDIX 9-1**

**SEEPAGE EVALUATION  
TASK 5.3.1.5.2 INITIAL SEEPAGE MODEL RESULTS MEMORANDUM**

TECHNICAL MEMORANDUM

South Florida Water Management District  
EAA Reservoir A-1  
Work Order No. 5

B&V Project 141522  
B&V File: C-1.3  
First Issue: July 11, 2005  
Last Updated: July 28, 2005

**Task 5.3.1.5.2 Initial Seepage Model Results Memorandum**  
**Seepage Evaluation**

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Seepage Evaluation**

To: Shawn Waldeck, Rich Bartlett

From: Kris Hahn, Ken Jones, Paul Petrey

**1. INTRODUCTION**

In October 2003, South Florida Water Management District (District) decided to pursue a “Dual Track” for the Everglades Agricultural Area (EAA) Reservoir project. While the multi-agency Project Delivery Team, led by the US Army Corps of Engineers (USACE), continues to develop the Project Implementation Report, the District is proceeding with the design of a reservoir (designated EAA Reservoir A-1 Project) located on land acquired through the Talisman exchange in the EAA.

The purpose of the EAA Reservoir Project as defined in the Comprehensive Everglades Restoration Plan (CERP) is to capture and store EAA Basin runoff and releases from Lake Okeechobee. The facilities will be designed to improve the timing of environmental water supply deliveries to Stormwater Treatment Areas 3 & 4 (STA 3/4) and the Water Conservation Areas (WCAs), reduce Lake Okeechobee regulatory releases to the estuaries, meet supplemental agricultural irrigation demands, and increase flood protection within the EAA.

Reservoir A-1 will be located in Palm Beach County about 14 miles south of Lake Okeechobee along the North New River Canal, as shown on Figure 1-1. The reservoir will be trapezoidal in shape, and at a depth of 12 feet it will have a storage volume of approximately 190,000 acre-feet. Reservoir dimensions will be refined through the design process, with provisions to control waves generated by wind action. Several gates are being evaluated along the perimeter embankment for the purpose of releasing water from the reservoir to the canals for irrigation and environmental demands. Several pump stations are being evaluated for the purpose of filling the reservoir by pumping water from the North New River Canal and potentially from the STA 3/4 Supply Canal. Seepage will occur from the reservoir and will be controlled by cutoff walls, seepage collection canals, and recirculation pumps.

**2. OBJECTIVE OF THIS MEMORANDUM**

The purpose of this technical memorandum is to provide a summary of preliminary seepage modeling results. Throughout the development of this model, there has been significant coordination between the District and the USACE, and this coordination will continue as we refine the model.

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EAA Reservoir A-1 will experience large water level fluctuations each year, as shown in the example given by Figure 2-1. The reservoir will be filled during the wet season (June – October) when water is available in the major canals and will be emptied during the dry season (November – May) to supply water for agricultural and environmental purposes. The seepage rate will be proportional to the depth of water in the reservoir. In the case of Figure 2-1, seepage will be greatest in January and February. A portion of the seepage will be collected by a new seepage canal that will be constructed around the perimeter of the reservoir, and a portion of the seepage will be collected by major canals such as the North New River Canal and the STA 3/4 Supply Canal. Pump stations will be designed to return the seepage collected by the canals back to the reservoir. Seepage not collected by the canals will escape to the surrounding areas including the farm lands, STA 3/4, and Holey Land.

A representation of anticipated seepage flow paths is given by Figure 2-2. Any seepage that escapes during the dry months may provide a benefit for the surroundings areas, and seepage that escapes during the wet months may pose some adverse effects. The farm canals may need to be pumped more than normal to return the seepage back to the North New River Canal to maintain acceptable groundwater levels for growing crops. If the farm canals cannot pump the additional water from seepage because it would exceed their permitted pumping rates or pump capacities, the groundwater levels in the agricultural lands will rise. Likewise, STA 3/4 and the Holey Land may need to be operated to handle the additional flow from seepage. This will be addressed in the final operations plan.

### **3. SCOPE**

The overall scope of services for the groundwater flow modeling includes the following tasks:

- Obtain and review data – This task also involved collection and interpretation of aquifer stratigraphy, hydrogeology, water levels, and aquifer characteristics for use in the EAA A-1 groundwater flow model. The results of the recent test cell program, USACE ongoing study, and several other past studies were reviewed to obtain information for the model
- Define model limits – This task involved defining the vertical and lateral model boundaries, model layers, and cell discretization
- MODFLOW model development –Using the results of the first two tasks, this task involved compiling the data and developing the groundwater flow model. Models were developed for both existing (pre-reservoir) conditions and various future conditions based on the proposed reservoir configuration alternatives
- Conduct initial reservoir simulations – This task involved initial model startup by working through a variety of issues associated with the input parameters and performing many verification analyses to determine the sensitivity of the model to these input parameters
- Information for Design Teams – Preliminary findings from these initial seepage simulations were provided to the various project teams to assist in the early stages of the reservoir conceptual design. Reservoir seepage will affect the results of the water balance of the A-1 reservoir, canal hydraulics, and pump station capacities

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- Calibrate hydraulic conductivity values for the model – A Test Cell Program was conducted in 2005 within the footprint of the proposed reservoir (see Figure 1-1). The Test Cell Program produced data including seepage rates from and water levels in two test cells and canal and aquifer water levels surrounding the test cells. As part of Work Order No. 2, two-dimensional SEEP/W modeling was performed to evaluate the data to determine hydraulic conductivity values for the aquifer layers. Parallel to that effort, in an attempt to verify and support the SEEP/W model results, a small-scale, three-dimensional MODFLOW model was also developed for the test cells. This MODFLOW model was also used to calibrate the hydraulic conductivities of the underlying aquifer layers
- Evaluate alternatives – Based upon the results of the above tasks, various alternative reservoir configurations and canal conditions were evaluated to identify the most effective method to control seepage from the reservoir and minimize impacts to surrounding areas. The results of these model simulations are also being used to determine the impacts of various storage times, water depths, reservoir filling cycles, and drawdown cycles, as well as aiding in the determination of seepage collection and return pumping

## 4. HYDROGEOLOGY

The EAA A-1 Reservoir site is located within the Everglades physiographic subdivision of Palm Beach County. The Everglades is generally flat, and the ground surface elevations within the area of the reservoir site are approximately 8 to 10 feet NAVD. Beneath the reservoir site, the geologic formations are grouped into three separate hydrologic units: (1) the shallow unconfined aquifer (surficial aquifer), (2) a lower deep confined aquifer system (Floridan Aquifer System), and (3) a middle unit that forms a confining bed (aquitard) separating these two aquifers. This evaluation focuses on the surficial aquifer.

The surficial aquifer consists of surficial peat and organic soils underlain by the Fort Thompson Formation of Pleistocene age, the Caloosahatchee Marl of Pliocene age, and the upper portions of the Tamiami Formation of Miocene age. The confining unit at the base of the surficial aquifer consists of the lower portions of the Tamiami Formation and the upper portions of the Hawthorn Formation, both of Miocene age.

Several significant hydrogeologic units were identified and confirmed during the Test Cell Program as follows:

### 4.1 *Muck/Peat*

The muck layer consists of generally organic deposits occurring at the ground surface. The muck soils can range in consistency from fibrous to granular and are a result of the deposition of decaying plant matter. Regionally, the thickness of these soils range from less than one foot to as great as 13 feet. Previous to agricultural and water level management activities in the study area, the thickness of these surficial soil deposits was as great as 17 feet. The muck soils are found to be permeable, with a large moisture storage capacity and a high capillary potential. Site specific information within the study area indicates that the average depth of the muck was found to extend to approximately 1.0 to 2.0 feet, below ground surface (bgs) with an average thickness of approximately 1.4 feet, ranging from 1.1 to 1.7 feet. Agricultural activities have reduced the thickness of the muck layer within the study area.

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#### **4.2 Caprock**

Underlying the muck layer across much of the reservoir area, there is a solution-riddled calcareous limestone layer referred to as “caprock”. The caprock has been considered to be part of the upper Fort Thompson stratigraphic unit, however for purposes of this study the caprock is being considered as a separate stratigraphic unit. Based upon soil borings and monitoring wells drilled throughout the reservoir site, the caprock has a thickness of approximately 3 to 10 feet (Black & Veatch, 2005; Williams Earth Sciences, 2004; Nodarse, 2002). The caprock and muck layers have been extensively breached by a large network of agricultural canals throughout the EAA.

#### **4.3 Fort Thompson Formation**

The sediments that comprise the Fort Thompson Formation are highly variable consisting of unconsolidated, calcareous and fossiliferous quartz sands to well indurated, sandy fossiliferous marine and freshwater limestone and clayey sand and sandy clays. The top of the Fort Thompson Formation is a hard limestone, which as discussed above is locally identified as caprock. Lower portions of the Fort Thompson Formation consist of interbedded layers of shell, calcareous marine sands (calcilutite), and thin layers of limestone. The sands are moderate brown to white, fine to medium grained, moderately rounded, with intergranular porosity. Pebble to cobble size limestone is present in the sand and shell layers. The limestone is light brown in color, microcrystalline and skeletal with moldic porosity (Scott, 1992). Based on boring log information, the thickness of the Fort Thompson Formation beneath the reservoir site is approximately 26 feet.

Observations made during the recent test cell program indicate that a significant amount of groundwater seepage occurs within or along the interface of the limestone layers within the Fort Thompson Formation. The limestone layers within the Fort Thompson Formation, including the upper caprock, were reportedly jointed and contained solution cavities and channels. The channels were several inches in diameter and appeared to fully penetrate the limestone layers. The solution channels within the caprock also contained soil including both peat and marl.

#### **4.4 Caloosahatchee Marl**

The Caloosahatchee Marl is similar in composition as the Fort Thompson Limestone consisting of sandy marl, clay, silty sand and shell beds, but generally has a higher quantity of silts and clays. However, the proportions of carbonate and quartz sand vary greatly within this formation. Based on borings drilled during the Test Cell Program, the top of the Caloosahatchee was encountered at a depth of approximately 30 to 40 feet bgs. Available information indicates that this formation thins from a thickness of about 70 feet at Belle Glade to about 7 feet near the Broward County Line.

#### **4.5 Tamiami Formation**

The Tamiami Formation consists of sand, clayey sand and poorly consolidated cream to white limestone and greenish-gray clay and marl. The permeability of the Tamiami Formation has been estimated by others to be moderate to low with the upper portions of the aquifer providing fair yields of water. It is difficult to differentiate between the Caloosahatchee and Tamiami Formation sands based upon soil borings, so it is common to refer to the shelly quartz sand encountered below the Fort Thompson as the Caloosahatchee/Tamiami Formation. For purposes

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of this seepage evaluation, the Caloosahatchee and the Tamiami are included as separate layers in the groundwater model which is consistent with other studies of the aquifer system in the area.

The lower portion of the Tamiami Formation and the upper portion of the Hawthorn Formation form the confining unit between the surficial aquifer and the Floridan Aquifer (Scott, 1992). The surficial aquifer extends to an approximate depth of -210 to -220 feet NAVD beneath the area of the reservoir site (Miller, 1987), so this depth was used as the base of the Tamiami Formation. Additional deeper borings are planned as part of Work Order No. 9 (Geotechnical Services) to help determine the depth of Tamiami formation.

#### **4.6 Hawthorn Group**

The Hawthorn Group is generally impermeable consisting of sandy, phosphatic marl, interbedded with clay, shell marl, silt and sand, forming the confining unit separating the surficial aquifer and the Floridan Aquifer. The deeper confined aquifer of the upper Floridan Aquifer System is composed primarily of limestone belonging to the lower portions of the Hawthorn Group, Tampa, Suwannee, Ocala, and Avon Park Formations. The groundwater model for Reservoir A-1 extends to the top of the Hawthorn Group.

## **5. MODEL DEVELOPMENT AND METHODOLOGY**

The Groundwater Modeling System (GMS) Version 5.1 was chosen to evaluate of seepage from Reservoir A-1. GMS is a proprietary software application developed at Brigham Young University that is capable of expediting the development and analysis of three-dimensional MODFLOW groundwater models. This is the same application that the Corps of Engineers is using for the Project Implementation Report (PIR).

Two MODFLOW groundwater models will be developed for this evaluation. A smaller scale model was developed for the area surrounding the test cells, and a larger scale model will be developed for Reservoir A-1. Steady-state conditions will be evaluated for both models. The test cell MODFLOW model was used for calibration of the hydraulic conductivities of the aquifer layers by matching model results to measurements taken during the Test Cell Program. The hydraulic conductivity values determined from the test cell MODFLOW model will then be used as input to the larger Reservoir A-1 MODFLOW model. The Reservoir A-1 MODFLOW model will be used to evaluate the effectiveness of a variety of seepage canal and cutoff wall configurations for different reservoir water levels. The results of the Reservoir A-1 MODFLOW model will be used to aid in the design of the seepage canal, the cutoff wall, and pumps to return seepage back to the reservoir. The results also show impacts to surrounding areas caused by seepage that migrates off-site.

### **5.1 Test Cell MODFLOW Model Development**

The Test Cell Program was conducted from January through May of 2005 within the footprint of the proposed Reservoir A-1 site (see Figure 1-1 for the location of the test cells in relation to the overall reservoir site). Two 500-foot square test cells were constructed and filled with water to a maximum depth of 12 feet; one test cell was constructed with a cutoff wall beneath the embankment, and one was constructed without a cutoff wall. A seepage canal was constructed around the perimeter of each test cell, and as seepage occurred from the test cells, water was recirculated from the seepage canals back into the test cells maintaining constant water levels in both the cells and the canals. Seventy-two piezometers were installed around the test cells, from

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which groundwater level measurements were taken during the operation of the test cells. Using the results of the Test Cell Program, a two-dimensional SEEP/W groundwater seepage model was developed and calibrated. For a more detailed description of the Test Cell Program and two-dimensional seepage modeling, a number of technical memoranda were recently submitted to the District (Black & Veatch, 2005).

Parallel to the two-dimensional SEEP/W seepage modeling of the test cells, a three-dimensional MODFLOW model was also developed to determine the vertical and horizontal hydraulic conductivity parameters for each of the aquifer layers underlying the site by matching model results to field measurements. The hydraulic conductivity values were varied within the model until agreement was reached between the model results and the following: (1) the groundwater levels measured in 65 piezometers installed around the test cells on 4/23/05 when equilibrium conditions were achieved for both test cells, (2) the water levels maintained in both test cells and test cell seepage canals on 4/23/05, and (3) the pumping rates from the seepage canals to the test cells required to maintain these constant water levels on 4/23/05.

The test cell MODFLOW model covers an area that is approximately 5.1 miles from east to west by approximately 4.2 miles from north to south. The model grid was aligned on a north-south and east-west pattern, since the general direction of groundwater flow direction is from north to south. The boundaries of the model were chosen significantly far enough away from the test cells to have no impact on the results obtained near the test cells and were assigned constant heads of 6.45 feet NAVD. The model was discretized with grid cells varying from 20 feet square in the vicinity of the test cells to 500 feet square near the boundaries of the model.

Vertically, the test cell model was divided into 4 aquifer layers as follows:

- The surficial muck/peat layer of between 1 and 2 feet thick was removed at the test cell site for reasons described in previous technical memoranda. Therefore, the muck/peat layer was not included in the model of the test cells
- Layer 1. Caprock. Top elevation 8 feet North American Vertical Datum of 1988 (NAVD). Bottom elevation 4 feet NAVD
- Layer 2. Fort Thompson Formation. Top elevation 4 feet NAVD. Bottom elevation -16 feet NAVD
- Layer 3. Caloosahatchee Marl. Top elevation -16 feet NAVD. Bottom elevation -60 feet NAVD
- Layer 4. Tamiami Formation. Top elevation -60 feet NAVD. Bottom elevation -210 feet NAVD
- The Hawthorn formation underlying the surficial aquifer was not included in the model. It was assumed that the top of the Hawthorn formation acts as a confining layer and restricts vertical movement of groundwater

The elevations for the interfaces between the aquifer layers were determined from borings at the test cell site. These borings did not extend to the bottom of the Tamiami formation. An elevation of -210 feet was obtained from a USGS map of the bottom of the surficial aquifer system (Miller, 1987). Several deep borings are planned for Work Order 9 to better define the

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bottom of the Tamiami formation. The deep borings may also provide information concerning the interface between the Caloosahatchee and Tamiami formations.

Two nests of three piezometers were installed midway along all four sides of each test cell in the bench between the embankments and the seepage canals. One nest of piezometers was installed near the downstream toe of the embankment, and one nest was installed near the seepage canal. Each nest of piezometers consisted of a shallow piezometer, a middle piezometer, and a deep piezometer. The shallow piezometers were screened in the Fort Thompson formation from a depth of approximately 6 to 16 feet NAVD. The middle piezometers were screened in the Caloosahatchee formation from a depth of approximately 32 to 52 feet NAVD. The deep piezometers were screened from a depth of approximately 72 to 92 feet NAVD in the Tamiami formation. This configuration allowed for measurement of groundwater levels in each of the formations that could be used to determine hydraulic conductivity values for the layers modeled.

The MODFLOW river package was used to simulate the known primary and secondary agricultural canals in close proximity to the test cells. The elevations of these agricultural canals were set to a constant elevation of 6.45 feet NAVD based on background measurements during the test on 4/23/05. The canal conductance, which governs the interaction of the canals with the aquifer, was set equal to 100 ft<sup>2</sup>/ft/day assuming a sediment thickness of 1 foot and a sediment conductivity of 1 ft/day.

The seepage canals surrounding each test cell were simulated as constant heads of 6.24 and 6.21 feet NAVD in the model to correspond to the levels the canals achieved on 4/23/05. The test cells were set at constant heads of 20 feet and 20.18 feet NAVD to represent water depths of approximately 12 feet in each cell on 4/23/05. MODFLOW's horizontal flow barrier package was used to simulate the 24 foot deep cutoff wall constructed for one of the test cells. A very low permeability was assigned to the cutoff wall assuming essentially no flow could pass through the wall.

## **5.2 EAA Reservoir A-1 MODFLOW Model Development**

The EAA Reservoir A-1 MODFLOW model covers an area from the Miami to Hillsboro Canals from west to east (approximately 22 miles) and from the Bolles/Cross to I-75 Canals from north to south (approximately 33 miles). See Figure 4.

The model grid was setup on a north-south and east-west pattern, since the general direction of groundwater flow direction is from north to south. The boundaries of the model were chosen significantly far enough away from the Reservoir A-1 site to have very little if any impact on the seepage results obtained for the reservoir. The boundaries were assigned constant heads that varied from 8.85 feet NAVD in the north to 8.6 feet NAVD in the south, providing a slight regional groundwater gradient across the modeled area. The model was discretized with grid cells varying in from 200 feet by 200 feet in the vicinity of the reservoir to approximately 4200 feet by 4200 feet near the boundaries of the model, with a total of approximately 470,000 cells. Vertically, the reservoir model was divided into the following 5 aquifer layers (see Figure 5):

- Layer 1. Muck/peat. Elevation range from 9 to 6 feet NAVD
- Layer 2. Caprock. Elevation range from 6 feet to 1 feet NAVD
- Layer 3. Fort Thompson Formation. Elevation range from 1 feet to -25 feet NAVD

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- Layer 4. Caloosahatchee Marl. Elevation range from -25 feet to -60 feet NAVD
- Layer 5. Tamiami Formation. Elevation range from -60 feet to -210 feet NAVD
- The Hawthorn formation underlying the surficial aquifer was not included in the model. It was assumed that the top of the Hawthorn formation acts as a confining layer and restricts vertical movement of groundwater

The elevations for the interfaces between the aquifer layers were determined from approximately 150 borings drilled by Williams Earth Sciences (2004) and Nodarse & Associates (2002) across the reservoir site. These borings did not extend to the bottom of the Tamiami formation. An elevation of -210 feet was obtained from a USGS map of the bottom of the surficial aquifer system (Miller, 1987). Several deep borings to define the bottom of the Tamiami formation and approximately 130 other borings are planned throughout the reservoir site as part of Work Order 9 that will provide additional characterization of the stratigraphy of the aquifer. The deep borings may also provide information concerning the interface between the Caloosahatchee and Tamiami formations.

The MODFLOW river package will be used to simulate the major canals within the modeled area such as the North New River Canal, the L-5 and L-6 canals, and the STA 3/4 Supply Canal. The canals are currently being added to the model, as are the seepage canal and cutoff wall.

Several water levels will be evaluated for the reservoir to develop a rating curve for the seepage rate. Obviously, seepage will increase with reservoir water depth. MODFLOW model runs were made for reservoir water depths of 1, 3, 6, 12, 15, and 18 feet.

## 6. PRELIMINARY MODEL RESULTS

As mentioned previously, the objective of the three-dimensional MODFLOW model of the test cells was for calibration to the data collected during of the Test Cell Program to determine horizontal and vertical hydraulic conductivity values for each of the aquifer layers that could subsequently be used as input for the larger MODFLOW model of Reservoir A-1. The results of this calibration provided a match for the seepage rates measured from both test cells and very good agreement between measured and calculated groundwater heads for the 65 piezometers included in the analysis. The results of the calibration are given in Tables 1 and 2. The horizontal ( $K_h$ ) and vertical ( $K_v$ ) hydraulic conductivity values used to obtain this calibration are given in Table 3.

These hydraulic conductivity values will be applied to the larger MODFLOW model of EAA Reservoir A-1.

For results associated with the larger model of EAA Reservoir A-1, refer to the Groundwater Model Memorandum (Black & Veatch, Hahn, Jones, and Petrey, 2005).

## 7. REFERENCES

Several sources of data were obtained and review to develop an initial understanding of the hydrogeologic framework of the aquifer beneath the proposed reservoir area. These sources included:

Bureau of Geology. *Appraisal of the Water Resources of Eastern Palm Beach County, Florida*. Report of Investigations No. 67. 1973.

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Central and Southern Florida Flood Control District. *Seepage Investigation for the Holey Land*. December 1975.

Dames & Moore. *Factual Report Submittal, Offsite Seepage Study, Stormwater Treatment Area 2*. Prepared for SFWMD. January 21, 2000.

USGS. *Hydraulic Conductivity and Water Quality of the Shallow Aquifer, Palm Beach County, Florida*. Water-Resources Investigations 76-119. April 1977.

Stormwater Treatment Area No 3 & 4. *Plan Formulation Document*. 2000.

SFWMD, US Army Corps of Engineers, Kimley-Horn and Associates. *Comprehensive Everglades Restoration Plan, Central and Southern Florida Project. B.2 Hydraulics, B.2.3 Hydrologic Model Calibration and Verification, Everglades Agricultural Area Storage Reservoirs – Phase I*. January 2004.

Central and Southern Florida Project, Comprehensive Everglades Restoration Plan, Everglades Agricultural Area Storage A-1 Reservoir Levee Optimization, Report for Conceptual Levee High Alternatives. May 2004.

Black & Veatch. Test Cell Program. Work Order No. 2. April - May 2005.

US Army Corps of Engineers. Project Implementation Report findings. Personal correspondence. 2005.

**Seepage Evaluation****Task 5.3.1.5.2 Initial Seepage Model Results Memorandum****TABLES****Table 1 Calibration of MODFLOW Model**

<b>Seepage Rates Measured during Test Cell Program on 4/23/05</b>			
	Measured	Calculated by Model	Difference
Test Cell #1 Seepage Rate	3,900 gpm	3,845 gpm	-1.40 %
Test Cell #2 Seepage Rate	1,900 gpm	1,895 gpm	-0.25 %

**Table 2 Calibration of MODFLOW Model**

<b>Groundwater Levels Measured during Test Cell Program on 4/23/05</b>			
Piezometers	Measured Head (ft NAVD)	Computed Head (ft NAVD)	Residual (ft NAVD)
PZ1/2BGNA	6.31	6.70	0.39
PZ1/2BGNB	6.57	6.80	0.23
PZ1/2BGNC	6.64	6.86	0.22
PZ1BGSA	6.28	6.60	0.32
PZ1BGSB	6.28	6.62	0.34
PZ1BGSC	6.35	6.63	0.28
PZ1E1	10.31	10.86	0.55
PZ1E2A	8.76	9.30	0.54
PZ1E2B	7.58	8.29	0.71
PZ1E2C	6.86	7.94	1.08
PZ1E3A	7.46	7.46	0.00
PZ1E3B	6.99	7.73	0.74
PZ1E3C	6.86	7.64	0.78
PZ1N1	9.51	10.83	1.32
PZ1N2A	8.4	9.07	0.67
PZ1N2B	7.42	8.21	0.79
PZ1N2C	6.88	7.89	1.01
PZ1N3A	7.26	7.31	0.05
PZ1N3B	6.93	7.69	0.76
PZ1N3C	6.75	7.61	0.86
PZ1S1	11.22	11.01	-0.21
PZ1S2A	8.5	9.40	0.90
PZ1S2B	8.24	8.30	0.06
PZ1S2C	7	7.94	0.94
PZ1S3A	7.35	7.45	0.10
PZ1S3B	7.17	7.73	0.56
PZ1S3C	6.83	7.63	0.80
PZ1W1	9	10.77	1.77

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Groundwater Levels Measured during Test Cell Program on 4/23/05			
Piezometers	Measured Head (ft NAVD)	Computed Head (ft NAVD)	Residual (ft NAVD)
PZ1W2A	8.76	9.24	0.48
PZ1W2B	7.58	8.26	0.68
PZ1W2C	6.86	7.91	1.05
PZ1W3A	7.46	7.41	-0.05
PZ1W3B	6.99	7.70	0.71
PZ1W3C	6.86	7.61	0.75
PZ21E	7.73	9.29	1.56
PZ21S1	7.67	7.11	-0.56
PZ2BGNA	6.24	6.55	0.31
PZ2BGNB	6.31	6.58	0.27
PZ2BGNC	6.36	6.61	0.25
PZ2E2A	7.55	6.94	-0.61
PZ2E2B	7.29	7.99	0.70
PZ2E2C	6.81	7.79	0.98
PZ2E3A	6.95	6.55	-0.40
PZ2E3B	6.96	7.45	0.49
PZ2E3C	6.74	7.47	0.73
PZ2N1	7.72	8.17	0.45
PZ2N2A	7.18	6.90	-0.28
PZ2N2B	7.18	8.02	0.84
PZ2N2C	6.74	7.80	1.06
PZ2N3A	6.69	6.50	-0.19
PZ2N3B	6.92	7.48	0.56
PZ2N3C	6.73	7.50	0.77
PZ2S2A	7.04	6.93	-0.11
PZ2S2B	7.16	7.92	0.76
PZ2S2C	6.83	7.76	0.93
PZ2S3A	6.56	6.49	-0.07
PZ2S3B	6.77	7.39	0.62
PZ2S3C	6.72	7.43	0.71
PZ2W1	7.78	7.11	-0.67
PZ2W2A	7.34	6.93	-0.41
PZ2W2B	7.06	7.95	0.89
PZ2W2C	6.78	7.78	1.00
PZ2W3A	6.68	6.50	-0.18
PZ2W3B	6.87	7.41	0.54
PZ2W3C	6.66	7.47	0.81
		<b>Average difference</b>	<b>0.49 feet</b>

## Seepage Evaluation

### Task 5.3.1.5.2 Initial Seepage Model Results Memorandum

**Table 3 Hydraulic Conductivity Values Determined with MODFLOW**

Layer	$K_h$ (ft/day)	$K_v$ (ft/day)
Muck/peat <sup>1</sup>	100	100
Caprock	500	1.1
Fort Thompson	400	10
Caloosahatchee	400	8
Tamiami <sup>2</sup>	36	18
<p><sup>1</sup> Muck was removed from test cells, so calibration to the K values for the muck was not possible. Initially used values determined by the Corps of Engineers through laboratory/field testing of the muck which were <math>K_h = 40</math> ft/day and <math>K_v = 9</math> ft/day, but increased these values to account for the significant area where muck does not exist (e.g., where the canals are located).</p> <p><sup>2</sup> The seepage from the test cells did not affect deep portions of the surficial aquifer, so calibration to the K values for the Tamiami was not possible. Used the Corps' values determined from laboratory/field testing.</p>		

## Seepage Evaluation

### Task 5.3.1.5.2 Initial Seepage Model Results Memorandum

#### FIGURES

Figure 1 A-1 Reservoir Location

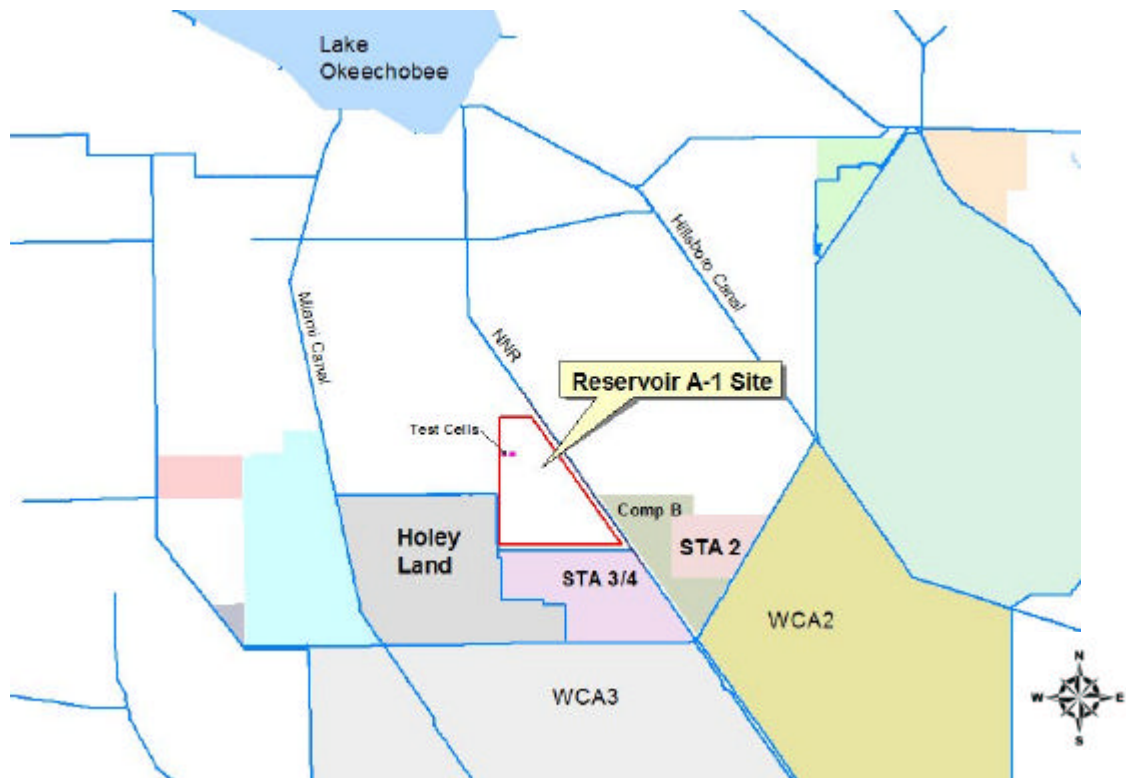
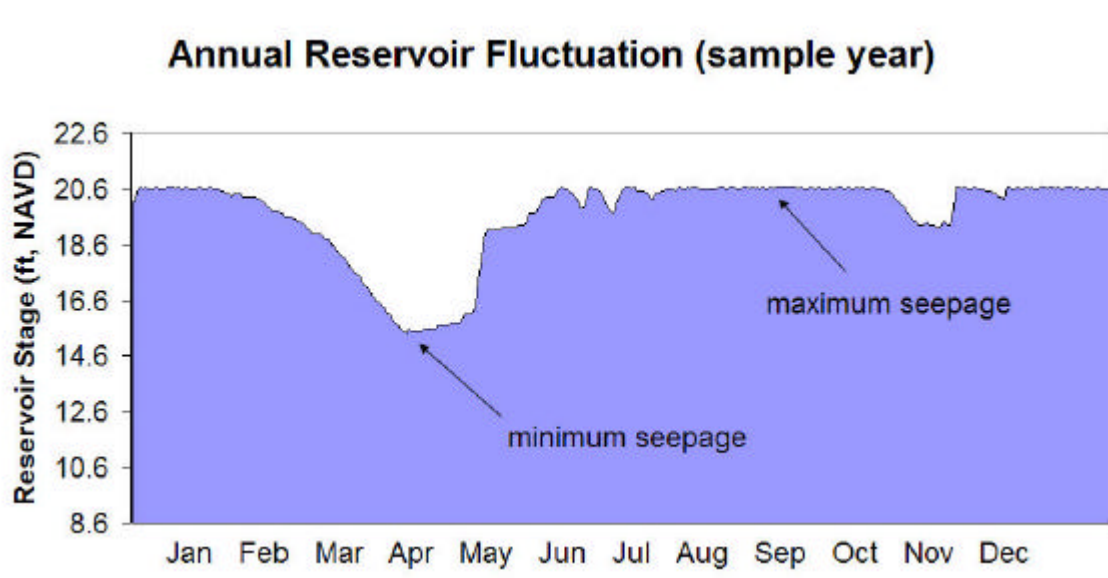


Figure 2 Example Reservoir Depth Fluctuation



## Seepage Evaluation

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Figure 3 Anticipated Seepage Flow Paths

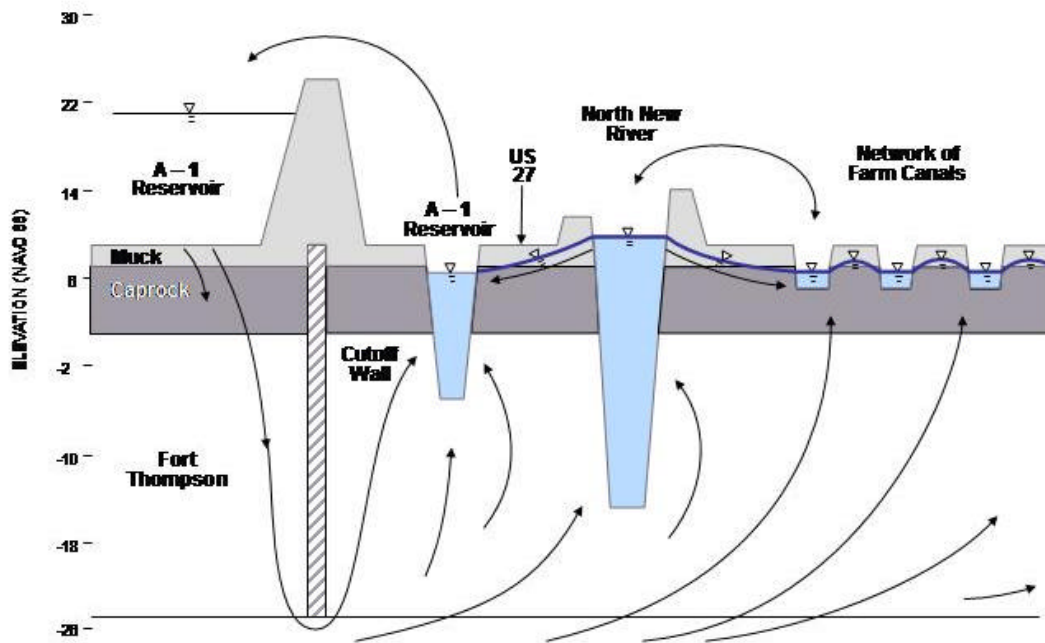
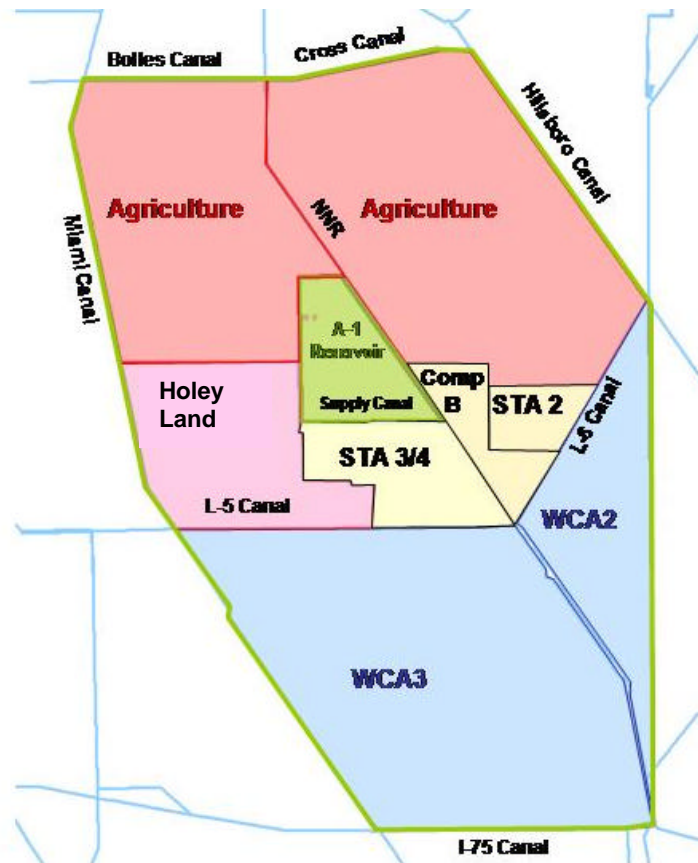


Figure 4 Extents of MODFLOW Model of EAA Reservoir A-1



## Seepage Evaluation

### Task 5.3.1.5.2 Initial Seepage Model Results Memorandum

Figure 5 Stratigraphy for Reservoir A-1 MODFLOW Model

